REPORT DOCUMENTATION PAGE

Form Approved
OMB NO. 0704-0188

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	05/30/01	Final Progress Report 09/01/95-08/31/99

4. TITLE AND SUBTITLE

Large Algorithmic Methods for Dynamic System Management

5. FUNDING NUMBERS

Contract: DAAH04-95-1-0607

6. AUTHOR(S)

~~Baruch Awerbuch~~ Frank Leighton

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Massachusetts Institute of Technology
Office of Sponsored Programs
Cambridge, MA 02139

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U. S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

32617.1-MA

11. SUPPLEMENTARY NOTES

The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.

12 a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release: distribution unlimited.

12 b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

See Report

14. SUBJECT TERMS

Algorithms, Dynamic System

15. NUMBER OF PAGES

3

16. PRICE CODE

17. SECURITY CLASSIFICATION OR REPORT	18. SECURITY CLASSIFICATION ON THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev.2-89)
Prescribed by ANSI Std. 239-18
298-102

MASTER COPY: PLEASE KEEP THIS "MEMORANDUM OF TRANSMITTAL" BLANK FOR REPRODUCTION PURPOSES. WHEN REPORTS ARE GENERATED UNDER THE ARO SPONSORSHIP, FORWARD A COMPLETED COPY OF THIS FORM WITH EACH REPORT SHIPMENT TO THE ARO. THIS WILL ASSURE PROPER IDENTIFICATION. NOT TO BE USED FOR INTERIM PROGRESS REPORTS; SEE PAGE 2 FOR INTERIM PROGRESS REPORT INSTRUCTIONS.

MEMORANDUM OF TRANSMITTAL

U.S. Army Research Office
ATTN: AMSRL-RO-BI (TR)
P.O. Box 12211
Research Triangle Park, NC 27709-2211

OCT 0 9 2001
By

- [ ] Reprint (Orig + 2 copies)
- [ ] Manuscript (1 copy)
- [ ] Technical Report (Orig + 2 copies)
- [x] Final Progress Report (Orig + 2 copies)
- [ ] Related Materials, Abstracts, Theses (1 copy)

CONTRACT/GRANT NUMBER: DAAH04-95-1-0607

REPORT TITLE: Large Algorithmic Methods for Dynamic System Management

is forwarded for your information.

SUBMITTED FOR PUBLICATION TO (applicable only if report is manuscript):

Sincerely,

Final Report
Contract: DAAH04-95-1-0607
09/01/95-08/31/99

Large Algorithmic Methods for Dynamic System Management

P.I.: Baruch Awerbuch
Johns Hopkins University
Computer Science Dept.
3400 N. Charles
Baltimore MD 21218
(202) 321 4444
(410) 516 6134
baruch@cs.jhu.edu

Research Objectives and Motivation / Statement of Problem Studied

The ability to predict the future would be an invaluable asset in many areas of human activity (e.g. investing in the stock market). Not surprisingly, the ability to predict the future would also greatly simplify management tasks for large computer systems and communication networks, where the inputs change in a dynamic fashion, and control decisions are made in an online manner. Examples of such management tasks include classical problems such as caching in a distributed system, routing in large networks, and resource allocation. Unfortunately, in reality knowledge of the future is often unavailable, which poses serious obstacles to efficiently utilizing system resources.

The issue of uncertainty-tolerant computing has been largely ignored by algorithm designers, who focused on developing elegant mathematical structures for solving traditional combinatorial problems. Our goal is to build new algorithmic primitives for handling issues of uncertainty. The comprehensive algorithmic theory of decision-making in the presence of uncertainty may be applicable in domains outside of computer science, including control systems, economics, manufacturing, etc.

Technical Approach Taken in this Project

Our general algorithm design philosophy can be characterized as "competitive algorithmic design", namely, we are pursuing algorithms that are "uniformly-efficient" on all inputs, not just on some "benchmarks" or "typical cases". In order to quantitatively reason about performance of online distributed strategies, we will be comparing their performance, on each input, against optimal prescient strategies, that know

the whole input ahead of time, pay no overhead for control, and have unbounded computational power. The competitive ratio of our strategy is the worst-case performance ratio over all possible input sequences.

"Competitive" algorithms complement algorithms based on experimentally-verified heuristics. Specifically, they can be combined with heuristics to yield solutions efficient both in the "typical" and "worst" cases. Finally, our approach is rigorous in nature. Analysis is developed that provides mathematical proofs for any claims of algorithmic performance.

Specific Accomplishments / Summary of Most Important Results

In the framework of our research effort, we have designed a number of competitive algorithms and rigorously proved their properties.

These include, among others solutions for the following problems:

1) Multicast admission control
2) Virtual circuit routing
3) Packet routing
4) Optimal switching policy at a router
5) Paging in networks with arbitrary topology
6) Packet scheduling
7) Minimum cost network design
8) Robot navigation and exploration of unknown terrain

Personnel

Baruch Awerbuch
F. Thomson Leighton
Steven Kouborov, partial support for Ph D.
Tripurari Sigh, partial support for Ph D.

Below we provide the list of publications supported by this grant.

Publications

B.Awerbuch and T.Singh, "Online Algorithms for Multicast and Maximal dense Trees", 29th ACM Symposium on Theory of Computing, 1997.

B.Awerbuch, A.Fernandez, J.Kleinberg, T.Leighton and Z. Liu, "Universal Stability Results in Adversarial Queueing Theory", 37th IEEE Symposium on Found. of Computer Science, November 1996.

B.Awerbuch. Y.Azar, A.Fiat and T.Leighton. "Making Commitments in the Face of Uncertainty: How to Pick a Winner Almost Every Time", 28th ACM Symposium on Theory of Computing, May 1996. Philadelphia, PA

B. Awerbuch, Y.Bartal, and A.Fiat, "Distributed Paging for General Networks", 7th ACM-SIAM Symposium on Discrete Algorithms (SODA), January 1996. San Francisco, CA.

B.Awerbuch, Y.Azar, and Y. Bartal, "Online Generalized Steiner Problem", 7'th ACM-SIAM Symposium on Discrete Algorithms (SODA), January 1996, San Francisco, CA.

B. Awerbuch and Y. Azar and O. Regev, "Minimizing the Flow Time without Migration", 31'st ACM Symposium on Theory of Computing (STOC 99).

B. Awerbuch, Y. Du, B. Khan and Y.Shavitt, "Routing Through Networks with Hierarchical Topology Aggregation", *Journal of High Speed Networks*. accepted for publication.

B.Awerbuch, M.Betke, R.Rivest, and M.Singh, "Piecemeal Graph Learning by a Mobile Robot", accepted to *Information and Computation.*

B. Awerbuch, K. Kalpakis and Y. Yesha, "Towards free Information Markets", accepted to *Mathematical Modeling and Scientific Computing.*

B.Awerbuch, Y.Azar, A. Fiat, S.Leonardi, and A. Rosen. "Online Competitive Algorithms for Call Admission in Optical Networks", accepted to *Algorithmica.*